The Penetron Conjecture:

Hypothetical Superluminal Non-Geodesic Particles and the Penetrability of Black Hole Event Horizons

v4: Integration with Thermal Conversion Gravity

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Abstract

We introduce the Penetron conjecture: the hypothesis that a class of hypothetical particles exists — called Penetrons — which travel at speeds $v > c$, do not follow the geodesics of spacetime, and are therefore capable of penetrating and traversing the event horizon of a black hole. The conjecture arises from a physical argument about the extreme density of black hole interiors and the necessity of non-geodesic superluminal motion for horizon crossing. We formalize the three defining properties of Penetrons, discuss their relationship to the black hole information paradox, and compare them to existing hypothetical constructs (tachyons, ageodesic particles). In this v4, we integrate the Penetron conjecture with the framework of Thermal Conversion Gravity (TCG) [1]: Penetrons are identified as the product of the first-order phase transition at the conversion surface $r_{\text{conv}} = 2r_s$ predicted by TCG, their equation of motion is written explicitly using the TCG coupling constant κ, and their properties in Kerr geometry are analyzed. This integration provides the Penetron with a dynamical origin and a calculable equation of motion for the first time. The conjecture is explicitly speculative and is presented as an open problem for theoretical physics.

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1 Motivation

1.1 The density argument

The interior of a black hole, under the gravitational collapse of stellar or galactic matter, accumulates compressed material over billions of years. The resulting density at and near the central singularity exceeds all known densities in the observable universe — nuclear density ($\sim 10^{17}$ kg/m^3) is itself already far below what the equations of general relativity predict near $r = 0$.

A useful physical analogy: consider used motor oil that has accumulated on the ground over time. Initially fluid, it condenses, thickens, and eventually hardens into a dense, nearly impenetrable substance. The black hole interior is the cosmic equivalent — matter compressed link by link, over cosmological timescales, into a state of extreme rigidity.

In such a medium, the void through which electromagnetic radiation propagates freely does not exist. Light, which achieves speed c in vacuum and slows in denser media (water: $v \approx 0.75c$; glass: $v \approx 0.67c$), would find no available path in the compressed interior. The refractive index $n \to \infty$ effectively, and $v_{\text{light}} \to 0$.

This is consistent with the geometric description: at the Schwarzschild radius $r_s = 2GM/c^2$, the escape velocity equals c and all outgoing null geodesics are bent back inward. The interior is sealed.

1.2 The penetration question

This raises a natural question: if ordinary particles and radiation cannot exit a black hole, could a hypothetical particle with fundamentally different properties — superluminal speed and non-geodesic trajectory — do so?

We call such hypothetical particles **Penetrons** and formalize their defining properties in the following section.

2 The Penetron: Three Defining Properties

Definition 1 (Penetron). *[Speculative/Open] A* Penetron *is a hypothetical particle characterized by the following three properties:*

(i) ***Superluminal velocity****: $v > c$ at all times.*

(ii) ***Non-geodesic trajectory****: the Penetron does not satisfy the geodesic equation*

$$\frac{d^2x^\mu}{d\tau^2} + \Gamma^\mu_{\nu\rho}\frac{dx^\nu}{d\tau}\frac{dx^\rho}{d\tau} \neq 0. \tag{1}$$

(iii) ***Horizon penetrability****: a Penetron can cross the event horizon $r = r_s$ in both the inward and outward directions.*

Remark 1. *Properties (i) and (ii) are logically independent. A tachyon (hypothetical superluminal particle in special relativity) satisfies (i) but still follows geodesics. The Penetron requires both: superluminal speed alone is insufficient if the particle still curves with spacetime geometry and is trapped inside r_s.*

3 Physical Interpretation

3.1 Why non-geodesic?

In general relativity, all particles — massive and massless — follow geodesics of the spacetime metric. Near a black hole, even radially outward geodesics are bent back inward for $r < r_s$. This is not a matter of speed: it is geometry. Spacetime itself is curved so steeply that "outward" is not a direction that leads out.

A useful physical intuition: a photon is like a leaf in a river — it goes where the current (curvature) takes it. A Penetron is like a motorboat with its own engine: it can cut across the current regardless of where the river flows. The river (spacetime) still flows inward. But the Penetron has a force f^μ and can head outward against the curvature.

Formally, the deviation from geodesic motion is written as:

$$a^\mu_{\text{Penetron}} = \frac{d^2x^\mu}{d\tau^2} + \Gamma^\mu_{\nu\rho}\frac{dx^\nu}{d\tau}\frac{dx^\rho}{d\tau} = f^\mu \neq 0, \tag{2}$$

where f^μ is the rigidity force that maintains the outward trajectory against spacetime curvature. In v1–v3, the nature and origin of f^μ was an open problem. Section 6 below provides its explicit form within TCG.

Particle	Geodesic?	Result at $r < r_s$
Photon	Yes	Trapped — follows curvature inward
Tachyon (geodesic)	Yes	Still trapped — follows curvature inward
Penetron	No	Can escape — resists curvature via f^μ

3.2 Why superluminal?

Proposition 1. *[Follows from Schwarzschild geometry] Any particle that exits a black hole interior from $r < r_s$ must satisfy $v > c$ at the moment of crossing the horizon.*

The event horizon condition in Schwarzschild geometry states that a particle at $r = r_s$ requires escape velocity $v_{\text{esc}} = c$ to exit. For $r < r_s$, the required escape velocity exceeds c. This is a necessary condition. Whether it is sufficient depends on the trajectory: a superluminal particle following a geodesic is still trapped inside r_s. Both properties (i) and (ii) are required simultaneously.

3.3 Connection to the information paradox

The black hole information paradox [4] asks: when a black hole evaporates via Hawking radiation, is the information encoded in the matter that fell in preserved or destroyed?

Current proposals (Page, Penington, Almheiri et al.) suggest information is encoded in Hawking radiation through subtle quantum correlations. All such proposals assume no classical channel exists between the interior and exterior.

If Penetrons exist, a new channel would be available: information could be carried outward by Penetrons crossing the horizon. This would resolve the paradox in a fundamentally different way — not through quantum entanglement of radiation, but through a new class of information-carrying particles.

Conjecture 1 (Penetron Conjecture). *[Open] There exists a class of particles — Penetrons — satisfying Definition 1. If such particles exist, they constitute a classical information channel between the interior and exterior of a black hole, providing a novel resolution mechanism for the black hole information paradox.*

4 Comparison with Existing Constructs

Particle	$v > c$	Non-geodesic	Horizon penetrability
Photon	No	No	No
Tachyon (SR)	Yes	No	No
Graviton	No	No	No
Penetron	Yes	Yes	Yes

The Penetron is distinct from all known hypothetical constructs. The tachyon travels faster than light but still follows the causal structure of flat spacetime and does not resolve the horizon problem in curved spacetime. The Penetron requires both properties simultaneously.

5 Three Mechanisms (v1–v3)

The first three versions of this paper identified three complementary mechanisms for Penetron production at black hole horizons:

1. **v1 — Horizon penetrability**: Any particle exiting from $r < r_s$ must have $v > c$. Penetrons satisfy this by definition.
2. **v2 — Pair creation**: Penetron/anti-Penetron pairs are created near the horizon by the strong gravitational field, analogously to the Schwinger effect. The outgoing Penetron carries energy and information.
3. **v3 — Conversion**: Infalling matter and photons are converted into Penetrons by the diverging acceleration in the near-horizon zone. Hawking radiation is the energy flux of this conversion product.

These three mechanisms are not mutually exclusive. They may all operate simultaneously, each dominating in different regimes of black hole mass, spin, and accretion rate.

6 Integration with Thermal Conversion Gravity (v4)

6.1 The TCG framework

Thermal Conversion Gravity (TCG) [1] is a scalar-tensor extension of general relativity in which a thermal scalar field $T(r)$, motivated by the Unruh effect, couples to the Schwarzschild geometry via a fully covariant action. Its central prediction is a first-order phase transition at the conversion surface:

$$r_{\text{conv}} = 2r_s, \tag{3}$$

derived without free parameters from the self-consistency of the Unruh field profile. All parameters of TCG are fixed by the black hole mass M alone.

6.2 The Penetron as conversion product

In the TCG framework, the Penetron is identified as the product of the first-order phase transition at $r = 2r_s$. This identification resolves Open Problem 4 of [1] and gives the Penetron a dynamical origin:

Conjecture 2 (Penetron as TCG Conversion Product). *[Open] At the conversion surface $r = 2r_s$, infalling ordinary matter undergoes a first-order phase transition — driven by the diverging Unruh temperature of the thermal scalar field — into Penetrons. The latent heat of this transition powers the outgoing flux identified with Hawking radiation.*

The three properties of Definition 1 are naturally satisfied:

(i) **Superluminal velocity**: at $r = 2r_s > r_s$, the effective speed of light is modified by the TCG thermal field. The Penetron is born in a regime where the local metric is dominated by the thermal scalar, allowing $v > c_0$.

(ii) **Non-geodesic trajectory**: the Penetron inherits the outward momentum of the converted matter. Its trajectory is governed by the TCG equation of motion, not the standard Schwarzschild geodesics.

(iii) **Horizon penetrability**: the Penetron is produced outside r_s (at $r = 2r_s$) and carries outward momentum. It does not need to cross the horizon outward — it is born outside it.

6.3 Explicit equation of motion

Within TCG, the force f^μ of Eq. (2) is no longer a free construct. It is derived from the action as the thermally induced geodesic deviation:

$$f^\mu = -\kappa(g^{\mu\nu} + u^\mu u^\nu)\,\nabla_\nu T, \tag{4}$$

where $u^\mu = dx^\mu/d\tau$ is the four-velocity and κ is the TCG coupling constant, fixed by Hawking consistency:

$$\kappa = \frac{8\pi G^5 M^5 k_B^3}{15\,\hbar^2 c^{13}}. \tag{5}$$

The projection $(g^{\mu\nu} + u^\mu u^\nu)$ ensures $f^\mu u_\mu = 0$: the force is purely spatial in the particle rest frame.

Remark 2. *[Important] The coupling constant κ depends only on M. The equation of motion of a Penetron is therefore entirely determined by the mass of the black hole that produced it. This is the first time the Penetron dynamics are calculable from first principles.*

6.4 The gradient at the conversion surface

At $r = 2r_s$, the thermal field gradient is:

$$\nabla_r T\big|_{2r_s} = -\frac{A}{2r_s^{3/2}}, \qquad A = \frac{\hbar c^3}{8\pi G M k_B \sqrt{r_s}}. \tag{6}$$

Substituting into (4), the radial component of the Penetron force at birth is:

$$f^r\big|_{2r_s} = \kappa\big(1-(u^r)^2\big)\,\frac{A}{2r_s^{3/2}}. \tag{7}$$

This outward force is what gives the Penetron its initial superluminal momentum.

6.5 Penetrons in Kerr geometry

In Kerr geometry, the conversion surface acquires angular dependence [1]:

$$r_{\rm conv}(\theta) = r_+ + \sqrt{r_s^2 - 4a^2} + \frac{2a^2 r_+ \sin^2\theta}{r_s^2} + O(a^4), \tag{8}$$

where $r_+ = r_s/2 + \sqrt{r_s^2/4 - a^2}$ is the outer horizon radius and $a = J/Mc$ is the spin parameter.

Polar Penetrons ($\theta \approx 0$): produced at $r_{\rm conv} \approx r_+ + \sqrt{r_s^2 - 4a^2}$, closer to the horizon for rapidly rotating black holes.

Equatorial Penetrons ($\theta = \pi/2$): produced further from the horizon by $\delta r = 2a^2 r_+/r_s^2$.

This angular asymmetry implies that Penetrons emitted at different latitudes carry different energies and momenta, producing a non-isotropic outgoing flux. In principle, this anisotropy could be detected as a deviation from the isotropic Hawking spectrum.

7 Open Problems

1. **Origin of the rigidity force** f^μ: Within TCG, f^μ is given by Eq. (4). Beyond TCG, the question of whether f^μ could arise from a different mechanism — a new fundamental interaction, or an emergent property of quantum gravity — remains open.

2. **Mass and spin**: What are the quantum numbers of a Penetron? A superluminal particle in special relativity has imaginary rest mass ($m^2 < 0$). In the TCG framework, the Penetron may have a real mass in the thermal metric while appearing tachyonic in the standard metric. The precise relationship is an open problem.

3. **Detectability**: If Penetrons exit black holes, what observational signature would they leave? The TCG framework predicts a depletion of classical matter emission in $r_s < r < 2r_s$ and an oblate anisotropy in Kerr. Could these be detected by existing or future instruments (EHT, ngEHT, LIGO)?

4. **Consistency with causality**: Superluminal particles generically threaten causality (closed timelike curves). Under what conditions, if any, can Penetrons exist without violating causality?

5. **Quantum extension**: In a full quantum gravity theory, do Penetron-like excitations appear naturally? Are they related to the island formula or replica wormhole constructions in recent holographic approaches to the information paradox?

8 Discussion and Scope

This paper is explicitly speculative. We do not claim that Penetrons exist. We claim that the question of their existence is physically well-posed, that their defining properties are formally consistent, and that if they exist, they have profound implications for black hole physics and the information paradox.

The v4 integration with TCG [1] represents a significant step: the Penetron transitions from a purely hypothetical construct to a dynamically grounded candidate particle with a calculable equation of motion. The rigidity force f^μ, previously an open problem, is now derived from the TCG action. The coupling constant κ, previously free, is fixed by the black hole mass M.

The name Penetron reflects the defining property: a particle that penetrates what nothing else can.

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